LITERATURE FOR 1911 ON THE BEHAVIOR OF ANTS AND MYRMECOPHILES

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Bouvier (1) observed the moving habits of the harvesting ant, *Messor barbarus*, at Royon. This ant nests in very large colonies in subterranean nests, of which one colony may have more than a single one. When conditions in one nest are unfavorable, the ants move into another taking with them their young and the stores of grain. During the process of moving a preliminary body of ants go out. These travel in two columns from one nest entrance to the other. The transportation of the larvae, pupae and the food supply is carried by a double column also. The small crustacean, *Platyarthrus hoffmanseggi*, which lives in great numbers in the nest entrances of *barbarus*, follows the ants from one nest to another, probably finding the new abode of the ants by the scent trail which these have left.

Buckingham (2) made very extensive experiments on the division of labor among ants as correlated with size and structural differences. The ants used were two species of Camponotus (*C. americanus* and *C. herculeanus pictus*) and three of Pheidole (*Ph. pilifera*, *Ph. vinelandica* and *Ph. dentata*). Camponotus was chosen because of the presence of large and small workers connected by intermediate forms, and Pheidole because it has small workers and large soldiers, without intermediate forms.

A tabular arrangement of measurements of Camponotus shows that there is a perfect gradation between the largest and the smallest workers, both in size and in structure. Structurally the queen is most closely related to the major worker. In Pheidole, no such intermediate forms exist, and the queen similarly is more like the soldier, though resembling the worker in certain characteristics.

In working with ants in artificial nests it was found that the ants were stimulated by a rise of temperature rather than by light, remaining quiet at 22° in a good light, but moving about

when the temperature was raised from 19° to 20° and 21° C. The stimulus was assumed to be not simply heat, but a rise in temperature.

Experiments were made with ants in Fielde, aluminum and Barth nests, and observations were made on outdoor nests. With the latter field notes were used, and ants engaged in various activities were collected and the data recorded. The activities tested were 1, foraging; 2, partaking of different foods; 3, feeding themselves; 4, regurgitating to others and receiving regurgitated food; 5, licking each other, likewise being licked; 6, tending the young; 7, building; 8, carrying other ants, likewise being carried; 9, surrounding the queen; 10, fighting; 11, responding to disturbances of the nest; 12, guarding; 13, scavengering.

An elaborate series of experiments was made, not only on the relation of the size to the labor, but also in regard to age. Callows, or recently hatched ants, acted chiefly as nurses, taking no part in the defence of the colony or in building. The size of the various workers was shown to be well correlated with the activities, most of the work in the nest and the foraging being done by the more active, smaller forms. The majors, both in Camponotus and Pheidole, were ordinarily sluggish, but easily stimulated by the nest's being disturbed, when they became more active than the minors in defending the nest. This is a valuable adaptation, keeping the majors in readiness and reserve for fighting. Buckingham shows that workers and even queens of various sizes participate to some extent in the activities of the colony, but a preponderant number of those working (with the exception of defending the nest, comparatively few of the ants in a colony are working at any one time) showed distinctly that the functions of the ants of different size are correlated with their structural differences.

Champlain (3) records the capture of *Xenodusa cava* in numbers in Connecticut, on tree tanglefoot which is used to trap the fall cankerworm. Ants also had fallen victims.

Cornetz (5, 6, 7, 8) and *Cornetz* and *Bohn* (11) in Algeria studied the homing of several hundreds of individual ants. Seven species were observed. An ant on going away from the nest strikes out in a definite direction, which it maintains in a general way throughout the out-going trip. From time to time

in searching for food it deviates but always resumes the original direction. To an ant (Messor) at several meters distant from the nest, Cornetz gave a seed. It took this in its mandibles, turned about and returned directly to the nest. This experiment was repeated a great many times, always with the same result. The line of return was more direct than the outgoing line, which was rather sinuous, with frequent deviations. The axes of these curves were followed in returning, and these led, with slight inaccuracies, toward the nest. In the immediate vicinity of the nest the ant stopped and searched for the entrance, showing here a realization of having gone a certain distance. This sense is quite variable. Sometimes the ant stops altogether too soon. When the ant first experimented upon was away from the nest Cornetz changed the aspect of the returning line by sweeping, digging ditches and bringing piles of earth or rubbish. The ant returned without hesitation, along a nearly direct line toward the nest. This experiment, which was repeated many times, shows conclusively that sight, smell, touch, chemotropism or topochemism play absolutely no rôle in the return of the foraging ant to the nest, except in the immediate vicinity of the entrance, when these senses may be brought into play. As far as these experiments went they seemed to show the existence of some mysterious "homing" sense, but further experiments were made that utterly disproved any such supposition.

On a plantain leaf, left in the vicinity of a nest until the ants had become accustomed to its presence, Cornetz placed a number of seeds. An ant (a large Messor) climbed upon this and seized one of the seeds. Cornetz carried the leaf several meters away and placed it again on the ground. The ant was then absolutely incapable of returning directly to the nest, but began to wander about, increasing the extent of its searching, but not further on one side of the point than on the other, until it approached the immediate vicinity of the nest. This experiment, repeated 150 times, always gave the same result. When carried to a distance of two or three meters from the nest, it took from a half to three-quarters of an hour before the ant could find the nest entrance, which, had the ant walked such a distance from the nest, would have taken only a minute or two. From this it is evident that the ant possesses no sense

of direction. The return after going out from the nest is explained by assuming that the sensorium of the ant receives a sensation of direction on the outward trip. This sensation is received at the beginning of the trip and maintained throughout its course, for no matter how many times the ant deviates from the general direction it returns each time. This phenomenon Cornetz calls "the constant reappearance of the once impressed wandering direction." This direction memory of the trail may be of greater complexity. When ants had become accustomed to a pile of grain at a certain point, the grain was removed some distance The ants diverged from the old spot, found the grain and returned to the point at which they had left the outgoing trail, and then went directly to the nest. Here a memory of two separate directions is shown. The secondary trails, diverging from the principal outgoing trail, were at right angles to it

Cornetz concludes from these observations that sight, smell, touch, chemotropism and topochemism play no rôle in the return of a solitary foraging or hunting ant, but that it is guided by an impression received by the sensorium at the beginning of the outward trip. From the fact that the outward trail is sinuous while the homeward is more direct, it is evident that the ant does not possess a kinometric muscular memory. Touch, smell and sight are probably valuable in guiding the ants in the immediate vicinity of the nest, where they lose the earlier impression of direction. But after a heavy rain, that had lasted two days and changed completely the general surroundings of the nest, the ants went out and returned as readily as before, when they had been familiar with the immediate vicinity of the opening.

Cornetz (9) reviews Santschi's paper "Observations et Remarques Critiques sur le Mecanisme de l'Orientation chez les Fourmis," in which the effect of the sun's rays was said to be an important factor in orientation. This phenomenon Cornetz calls the "solar tropism of Santschi." He considers that it helps greatly in explaining the constancy of orientation, but doubts its application to ants moving about in the deep woods, or in the shade in general, unless we assume that certain as yet unknown rays of the sun penetrate through walls, trees, etc., not being absorbed by these bodies. When the sun was

very high, Santschi's experiment was not successful, and Cornetz points out that beneath the equator, with the sun more or less perpendicular to the line of march, the ants are able to maintain their direction.

Cornetz notes a case of a memory of direction in *Myrmecocystus bicolor,* which had moved from one nest to another, and for a long time traveled between the old and new nests.

Davis (12) records the occurrence near Clayton, Georgia, of a mixed colony of *Formica exsectoides* and *Formica subsericea,* representing one of the stages in the colony formation of the former species, which is a temporary social parasite.

Donisthorpe (13) placed the larvae of a Chrysomelid beetle (*Cryptocephalus fulvus* Greg.) in a plaster nest with a few of its host ant, *Lasius fuliginosus.* The larva acted like that of the related genus Clythra, crawling about and feeding on the refuse of the nest, and enlarging its case as it grew. When the adult beetle emerged it was torn to pieces, either by the ants or by other myrmecophiles (Myrmedoniae) which were present. In nature the mature beetle would escape from the nest.

Donisthorpe (17) placed workers, eggs and larvae of *Formica exsecta* Nyl. into a small nest of this species which the year before had been taken near the same spot. The workers intermingled freely and behaved in a friendly manner towards one another. He records *Lasius umbratus* as collecting small empty land shells, and sitting on them. No explanation is offered of this curious behavior.

Two colonies of *Leptothorax acervorum* were placed together. and apparently affiliated to form one colony. Donisthorpe has never reared a female from eggs laid in captivity, and suggests that the juices obtained from aphids may be necessary to the development of the female larva.

The myrmecophilous beetle *Atemeles emarginatus* Pk. was taken from a nest of its winter host *Myrmica scabrinodis,* and placed in a nest of *Formica fusca.* The beetles remained away from the ants for twenty-four hours, when, joining the ants, they were readily received. This is regarded as additional evidence that these beetles go into quarantine when leaving the nest of one species of ant before entering that of another.

A spider, *Asagena phalerata,* was observed catching ants (*Myrmica laevinodis*). It kept at some distance from the ant

and "threw the threads" of web at it. Four or five ants were entangled together and carried off. The mite *Laelaps cuncifer* Mich. was observed to follow the "tracks" of the host ant when it went from one nest compartment to another.

Donisthorpe (15) records observations on the behavior of certain ants that are temporary social parasites. Experiments were made with *Formica sanguinea* Latr., the only English slave-making ant, and its host, *Formica fusca*. Workers and pupae were placed in one compartment of a "Crawley" nest, and two females of *sanguinea* in another. As soon as the latter became aware of the presence of the *fusca* cocoons, "they hurried in, attacked and killed the *fusca* workers and carried the cocoons to their own compartment." The adults from *fusca* cocoons which were placed in the nest, were assisted in emerging by the *sanguinea* queen.

To prove that *sanguinea* females are unable to found colonies by themselves, Donisthorpe placed several in bowls. They hid beneath pieces of sponges, but made no attempt to dig cells. A few eggs were laid, but neglected, and therefore did not hatch, thus corroborating other experiments and seeming to indicate positively that *sanguinea* depends absolutely upon a temporary host to found a colony.

Emerton (18) states that the spider *Phrurolithus formica* Banks is found only in the nests of *Cremastogaster lineolata*. In the spring, when the ants are gathered under stones over their burrows, the spiders are found among them. If not frightened, they move about slowly, like the ants, but when frightened are much more active, and run either into the ant burrows or into the grass about the nest.

Emery (20, 21) studied the mating and colony-founding habits of Polyergus. There is no doubt that marriage-flights occur frequently with Polyergus, but copulation may also take place in the nest. Queens, both dealated and winged, have been frequently observed in company with raiding-columns. In one colony observed by Emery for two years, the marriage-flights occurred the second year, but not during the first. The first year, queens were found with raiding-armies. Of these Emery sent one dealated specimen to Silvestri, who found the *receptaculum seminis* full of sperm. A winged female taken at the same time was not fertilized. No queens were found in the

columns of workers outside the nest during the second year, and Emery considers it possible that marriage-flights may depend on the number of sexual forms, especially of males. Where there are only a few of these copulation takes place in the nest.

In founding a colony, one or more Polyergus queens enter the nest of *Formica fusca* or some variety of that species. When not prevented by the workers the parasitic queen goes directly to the *fusca* queen and kills it by piercing its brain with the sharp mandibles. The demoralized *fusca* workers then readily adopt the alien queen. Some of the Polyergus were killed by *fusca* workers before reaching the queen. This was in a Janet nest, which is particularly favorable to the Polyergus queen. In nature the killing of parasitic queens probably occurs more often.

It is important to Polyergus that the host colony be populous. This Emery believes to be true of all parasitic ants. If the colony selected by the queen is small, the primitive stage of the Polyergus colony may last two years. During the first year no eggs are deposited The second year eggs are laid and workers develop, but no raids are started until late in the summer, sometimes not until the third year, when the colony is fully developed.

Emery (19) studied the relations of fecundated females of *Pheidole pallidula* toward each other. They oviposit a few days after fertilization, and when placed together in an artificial nest fight and tear the antennae and legs of one another. The individuals without antennae become indifferent to the eggs, so that their care falls to the lot of the female that has preserved her appendages. Eggs laid early in July gave rise to workers August 15th. After three separated females had been permitted to bring up their broods, Emery made openings between their cells. The workers at first tried to obstruct the openings. The workers of two of the colonies fought with one another. When the queen of one of these was killed her brood was appropriated by the other. Later the two remaining colonies behaved in the same manner till only one female remained and the broods of all three colonies were united. When several females were permitted to found their colonies in close proximity to one another, similar results were obtained. Emery concludes that recently fecundated queens of *Ph. pallidula* live together amic-

ably till they have oviposited, but that discord supervenes with maternity and the attraction of the ova.

Experiments with dealated queens of Tetramorium yielded somewhat similar results, but out of fifteen queens that reared their broods together, three survived. In other species of ants the queens are even more tolerant of one another, e.g., *Plagiolepis pygmaea* and *Leptothorax unifasciatus*. In this connection Emery calls attention to the Argentine ant (*Iridomyrmex humilis*), the colonies of which, according to Newell, may unite in great numbers in the fall, producing enormous hibernating colonies, each containing hundreds of queens.

Emery (22) shows that larvae which are insufficiently nourished produce weak and undersized workers. These inferior workers are found in the first brood of a queen and in colonies where the worker force is small numerically. As the success of a colony of robber-ants depends on the presence of large, strong workers for fighting, Emery considers that a populous host colony is necessary. Social parasitism having arisen, in the opinion of Emery, from nest-robbing habits, this necessity for a large force of workers to attend the young has been an important factor in its origin.

There is no transition in habit from the forms of *fusca*, through to the typical social parasites, *rufa*, *truncicola*, etc., so Emery considers that the social-parasitic habit originated from a mutation rather than by a gradual development. In *sanguinea* the mandibles of the male are toothed, while in *fusca* they are smooth, which shows that the latter species is even more specialized than the former.

Enslin (23) observed *Formica cinerea* attending the small European Membracid, *Gargara genistae*, which he found in numbers on *Sarothamnus scoparius*. The plant was frequented by ants which were foraging and also attending a few aphids in the ordinary manner. When one of the ants finds a Gargara nymph it strokes the abdomen with its antennae. The treehopper elevates the abdomen and from the anus exserts a rod-like structure on the end of which is a drop of light-colored liquid which the ant imbibes. Then the ant either tries again on the same individual or hunts for another. If the head or thorax instead of the abdomen of the bug is stroked the result is the same. Adults of Gargara are also attended, but not so

frequently as the immature stages, possibly because the drop is harder to get at on account of the wings. One adult was stroked for some time by an ant and failed to respond, but a half minute later when the ant had gone it spontaneously ejected a large drop, which was found and lapped up by another ant.

Enslin placed specimens of both the immature and mature phases of the tree-hopper in the immediate vicinity of a *cinerea* nest. Sometimes an ant received a drop of secretion from the Homopteron and went on its way. Others took the insect in their mandibles and attempted to take it into the nest, sometimes successfully. At other times the insect struggled too much. The fate of those taken into the nest was not observed. Without access to its food plant the insect could not secrete the liquid for which the ants attend them; besides, those which Enslin kept without food died within two days. It may be that those adults brought in after copulation deposit eggs in the nest, but nothing definite regarding this is known. In fact, only scant observations on the relations between any Membracids and ants have been recorded.

Escherich (24) in Ceylon studied the "myrmecophilous" plant Humboldtia, the stems of which have hollow internodes, each with an opening at the upper end. The leaves are provided with nectaries that afford a food supply to ants, several species of which nest in the hollows, and Schimper had considered the plant typically myrmecophilous. Escherich found that only a small percentage of the internodes were used as nesting sites by ants, and that these were species which nest in various other places also. Unless the twigs were violently shaken the ants made no attempt to defend the plant. Many of the occupied stems showed scars made by woodpeckers attracted to the ants, so Escherich concludes that the relationship between plant and ant is in no wise symbiotic, but rather parasitic, as the latter derives its shelter and food from the former, giving no service in return, and even being directly harmful through attracting enemies. Escherich believes that records of symbiosis based on the study of the plant structure only, without observations on actual relationships, are not worthy of consideration.

In Abyssinia Escherich observed the foraging habits of a species of Messor. During the day the ants remained in the nest. At nightfall they emerged, leaving the nest by a distinct trail

which was followed 30 or 40 meters. Then they spread out, some climbing weeds in search of seeds. When food was found the ants returned by the same trail, which was then being traversed by two files of ants moving in opposite directions. The seeds gathered were of numerous varieties. Some of the foragers returned carrying lumps of earth, small stones or other worthless objects, a fact tending to show variability in the grain-collecting instinct. At the nest entrance several large workers acted as guards and examined with their antennae the returning workers before allowing them to enter the nest. The husks from seeds were brought out of the nest very quickly and taken to some distance.

Among the foods collected by the ants were many tubers from the root stalks of *Cyperus bulbosus*, which are eaten also by the Abyssinians. Their carrying these about may possibly be of importance in the dissemination of the plant species.

Goeldi (25), in an account of the structure and character of the ant nest, introduces the term Gonepitropy for the assumption of the reproductive functions by the queen. The workers have taken over the functions of food-gathering and nursing for the entire colony, and this Goeldi calls Ergepitropy. The workers Goeldi does not consider to be degenerate females, but rather a distinct caste, fitted for the work that is done by them.

Krausse (26) records a few observations made on *Aphaenogaster sardoa*, a characteristic Mediterranean ant. The holes in which this ant lives are not dug by it, but have been made previously by other animals or natural means. In the fall the ants cluster into a ball, holding on to each other with mandibles and tarsi, with the eggs, larvae and pupae in the center, and remain in a semi-dormant condition. This habit is analogous to the hibernation of northern ants. In summer the clustering habit to some extent persists, but the ants are much more active. Krausse placed a number of workers with pupae in a glass nest and after a half hour found them in a compact cluster, the pupae in the middle. When dispersed, they again built a cluster. No myrmecophiles were found with *sardoa*, and Krausse considers their absence related to the non-harvesting and non-cell-building habits of the ant. The larva-robbing Dermapteron, *Euborellia moesta*, which steals from the nests of other ants in the same vicinity, was not found with Aphaenogaster,

probably because of the larvae being in the center of the ant cluster where they can be taken only by a direct attack, a method to which few inquilinous thieves resort.

Krausse lists a number of ants which are known to possess stridulating apparatus. In some of the species the sound produced is loud enough to be heard by the human ear.

Krausse (27) in Sardinia found carton nests built beneath stones by *Cremastogaster scutellaris* Besides *C. scutellaris*, *Lasius fuliginosus* and *Liometopum microcephalum* are European ants which make carton nests.

With *C. scutellaris* myrmecophilous insects were rare. One specimen of the robber earwig, *Euborellia moesta*, was found in the nest of this ant.

Krausse (29) observed two ant trails which crossed each other. The trails were made by different species of Messor, and led from nests which were very close together. Ants in the files going and coming showed sometimes a little excitement at the point of crossing, but no actual fighting took place. They would lunge at each other without taking hold.

Krausse (28) records an earwig, *Euborellia moesta* as occurring commonly in the nests of several ant species in Sardinia. Its relation to the ants is that of a robber, and it destroys large numbers of the larvae. *Forficula auricularia* was also observed to enter ant-nests and feed on the immature stages.

Leonard (30) records observations made on "honey" ants, *Myrmecocystus mexicanus mojave*, *M. mexicanus* and *M. melliger lomaensis*, all found on the grounds of the Raja Yoga School at Point Loma, Cal. *M. mojave* prefers a moist soil in which to nest. Leonard believes that the large entrances to the nests are required for the removal of iron nodules encountered in digging, and not for purposes of ventilation as suggested by Wheeler. This new view presupposes large quantities of iron nodules in all regions inhabited by *mojave*, for the habit of making large entrances is characteristic of the insect throughout its geographical range.

Individuality in character was shown by a minor worker. When one of the ants had fallen into a moat two workers discovered and inspected it without offering aid. Then the minor approached and "showed the liveliest concern. For many

minutes she vigorously kneaded the patient's gaster, and worked the stiff legs until at last the half-drowned ant revived." The ants gather honey from blossoms of a pepper tree (*Schinus molle*) and from *Euphorbia setiloba, Echinus simplex, Ceanothus cuneatus.* and from aphids

Callows, after emerging, were carried out of the nest by older workers "as a hint that they might now undertake the regular work of the nest."

Myrmecocystus mexicanus was observed to lap the honey contents of dead repletes, contrary to the recorded observations of McCook on the var. *horti-deorum. Myrmecocystus lomaënsis,* a diurnal species, became violently excited when it was offered bee's honey.

Miehe (32) studied the plant Myrmecodia in Java in relation to ants. *Myrmecodia tuberosa* possesses a swelling in the stem, originating from the hypocotyl. This swelling is perforated by a complicated system of cavities. One or more large openings connect these with the surface, and smaller openings are also present. In the inner spaces of the cavities numerous species of ants take up their abode. These sally out when the host plant is struck, but are not particularly aggressive.

Forbes and Treub found that these cavities were developed without the presence of the ant, in contradiction to earlier opinions. Treub considers that they are useful to the plant in transpiration. Kaesten regarded the swelling as an organ for the economy of water, the wart-like objects (*lenticels*) which line the cavities being absorbent organs, and Miehe also considers them to have the same function They are also supposed to excrete water.

One part of the cavity walls is light in color, smooth and without tubercles, the other is tuberculate and dark in color. On the latter surface flourishes a fungus, which in the opinion of Miehe grows on the excrement of the ants. The ants have their larvae and pupae always on the smooth surface, and deposit their excrement on the rough part, a habit similar to that recorded by Von Ihering for the Azteca queens of the South American Cecropias. According to Miehe the food products in the ant excrement must be important to the epiphyte.

The fact that the ants drop their excreta on the exact place where the absorbing organs are situated, and that this is of

importance to the plant, is taken as evidence of myrmecophily, but whether the dung is actually necessary to the growth of the plant is not known. The plant has few natural enemies, so its defense by the ant is not to be considered. *Iridomyrmex myrmecodiae* lives in other places as well as in the hollows of Myrmecodia, so that the plant is certainly not necessary to the ant. *Hydnophytum montanum* is recorded as having similar relations to the ants.

Nickels (33) experimented as to the possibility of exterminating the Argentine ant (*Iridomyrmex humilis*) with entirely satisfactory results. Sponges, moistened with sugar syrup, containing one-fourth to one-eighth per cent. sodium arsenate, were placed in the neighborhood of the nests. This was eaten by the ants, and fed to the queen and brood, slowly poisoning them and shutting off the increase of the colony.

Polimanti (34) in Naples observed large numbers of the winged forms of *Lasius niger* attracted to large arc-lights, while comparatively few came to incandescent and other less bright lights. He attributes this to simple phototropism.

Poulton (35) published some notes made by Lamborn, who had noticed that the larvae of Lycaenidae in the Lagos district were often attended by ants. Examination of the ant-nests in the hollowed head of a plant (*Castus afer*) showed that each contained several caterpillars and pupae. These were attended and licked by the ants, but the adult butterfly was killed and eaten. Lamborn observed the ant *Oecophylla smaragdina* attacking the larva of a Lycaenid. This ant has been observed frequently to tend the caterpillars. The larva of a Pyralid moth also lives in the nest.

Reichensperger (36) confirms the observations of Wasmann that in nests of *Formica sanguinea* infected with the beetle Lomechusa, normal queens and pseudogynes are not developed at the same time. The pseudogynes which he found were intermediate between those forms which Wasmann calls Mikro- and Mesopseudogynes. The percentage of these abortive females in the brood gradually increased, the slave-making raids were not continued, and those pupae already taken were not cared for, the result being the weakening and the final disintegration of the ant colony, as a result of the presence of Lomechusa.

Reichensperger observed for the first time the first stage in the temporary social parasitism of *Formica pratensis* in the nest of *Formica rufibarbis* var. *fuscorufibarbis*. The alien queen was very readily adopted, "treated as though she were the only one," one beginning to lay eggs after one week. *Pratensis* queens are not always so successful, as was shown by the finding of dead and dismembered individuals in other nests of *rufibarbis*.

Reichensperger records the discovery of a microgyne of *Plagiolepis pygmaea*. One of these small queens in an artificial nest laid eggs from which normal workers were reared. The microgynes were similar to the queen in structure, but in size about as large as the workers, from which they differed in color as well as structure.

In a postscript Reichensperger states that he may not have been correct in his specific determination. The microgyne may have been a guest species, or an incipient new species derived from *P. pygmaea*.

Sadownickowa (37) made a series of 42 stereoscopic photographs of various activities of European ants. Among the lot are pictures of the nests of several species, life histories, foraging individuals, parasitic colonies, fighting, and mixed colonies. Photographs No. 40 and 41 show ants of different species, from which the antennae have been removed, living peaceably together. In the lot are workers of *Camponotus ligniperdus*, *Formica sanguinea*, *Formica rufa*, *Formica fusca*, *Messor barbarus*, a female of *Formica sanguinea* and a male of *Lasius niger*, all feeding on honey water. The antennae of the male have not been removed, but it is apparently unable to distinguish between friend and foe.

Santschi (38) studied the behavior of several species of North African ants in regard to orientation. Certain of these (*Acantholepis frauenfeldi* and *Tapinoma nigerrimum*) made a scent trail by touching the tip of the abdomen to the ground. *Myrmecocystus bicolor*, with the antennae removed, found the nest, at first wavering somewhat but more directly as it neared the nest, evidently familiar with the immediate approach. Here sight seems to be an important factor. *Messor barbarus* proceeded in the general direction of its nest, though the ground over which it had come had been swept and otherwise disturbed,

so as to leave no possibility of guidance by scent or the sight of immediate objects. The sight of this ant is poor so that objects at a considerable distance from the ant could have had no effect, so the experiments agree with those of Cornetz and other workers in showing the constancy of conservation of orientation. Santschi explains this by assuming that on the outward-going trail certain rays of light (probably ultra-violet) make an impression on the pigment of the ant's eye. Owing to the structure of this organ these impressions are unequal in various parts and are retained, making a sort of compass to orient the ant on its return. By means of a mirror, Santschi changed the direction of the light rays on homeward bound ants. Under this influence the ant changed its course, but orientated itself toward the nest when the mirror was taken away. Santschi considers the "homing" sense a very complicated phenomenon, involving many factors; but above all, the perception of these physical rays, visible or not to us, is valuable as a basis for orientation.

Tanquary (39), in order to determine whether they would be adopted, placed queens of *Aphaenogaster tennesseensis* with colonies of *A. fulva, A. fulva aquia, A. fulva aquia* var. *picea.* In all cases the queen was eventually killed by the workers of the other species, but a tendency toward adoption was shown by the fact that the queen was often licked by the workers. A queen of *A. tennesseensis* was placed with pupae of *A. aquia.* She paid no attention to these. Some hatched, and at first the queen remained by herself, but afterwards stayed with them, and was readily adopted, as in the cases recorded by Miss Fielde (Artificial Mixed Nests of Ants).

Queens of *Formica rufa* subsp. *obscuriventris* were placed with colonies of *Formica fusca subsericea.* Where the colony was large, the queen was killed; when small, after being attacked for a time, she was finally adopted. The queens showed decidedly inquilinous habits, and this, with the fact of their being adopted by small colonies, with the previous finding of a mixed colony in nature, shows that *F. obscuriventris* is, at least occasionally, a temporary social parasite in the nests of *F. subsericea.*

Experiments were made with 79 queens of *Lasius* (*Acanthomyops*) *latipes,* introducing them into different colonies of other

species of Lasius. Of all these, only two queens were completely adopted. This low percentage can be partially explained by the difficulty of keeping queens of *L. latipes* alive in confinement. It is doubtful if in nature even this small proportion of the queens succeed in forming colonies, for colonies of the species are not very abundant, in spite of the fact that a great number of queens are produced in each colony.

Queens of this species and of *Lasius americanus* were placed together. Neither species showed hostility toward the other, though their temperaments were decidedly different, *latipes* being very restless, and running constantly about. The fact that both species of queens lived amicably together might be taken to indicate that mixed colonies may be founded in common by two queens of different species, but the nervous behavior of *latipes* and its attraction to any brood, with which it settles contentedly, is taken by Tanquary to show that it is more plausible to believe that this species is a temporary parasite.

Experiments were made with 88 queens of *Lasius umbratus* var. *minutus* and workers of several other Lasius species. Of this lot only one queen was adopted by *L. americanus*. But this one case indicates that *minutus* is parasitic on *americanus*. The *minutus* queens are feeble, and easily killed, succumbing to treatment that would not be fatal to ordinary species. The sporadic occurrence of the species, with the large number of queens produced (a quart of earth from the one nest was found to contain about 150), is taken as justification of this conclusion.

Queens of *Polyergus lucidus* were placed with colonies of *Formica incerta* and *F. schaufussi*. The queens were attacked by the workers, but defended themselves with vigor, one of them killing all of the fifteen workers with which she was confined. In two experiments the queen was adopted by *incerta* after being at first attacked. An *incerta* queen in one of the nests was killed by Polyergus, after which the workers adopted the alien queen. In no case did any of the Polyergus queens pay any attention to the young.

Queens of *F. nepticula* were tried with colonies of *F. incerta*, *F. fusca* var. *subaenescens* and *F. neogagates*. With the first two the results were negative, the queen being killed very soon,

but with *neogagates* the attacks were not so fierce. Several times workers were observed licking her, and she was twice observed feeding a worker. She was finally killed.

Viehmeyer (40) studied the mating flights in several species of ants. These flights have a double purpose, to distribute the species and to prevent close inbreeding. The flights of the same species occur at approximately the same time, and at these times sexual forms from many nests mingle together in an enormous swarm, so that the individuals from one nest copulate with those from another. The wings of queen ants are very brittle and weak, and the presence of a strong wind blows the ants about, scattering the species to long distances.

Often many species of ants have their mating flight at the same time, and join in one common swarm. One of these swarms was observed by Viehmeyer. It consisted of two species, *Myrmica scabrinodis* and *M. ruginodis*, with the latter greatly predominating in numbers. When numbers of pairs had fallen to the ground they were collected. Of the lot, only about one-sixth were of the same species, and in every case these were *ruginodis*. Most of the couples consisted of a *scabrinodis* queen and a *ruginodis* male. The males of both species predominated in numbers over the females. Hybrids between ants are sterile, and Viehmeyer does not consider that hybridization has any importance in the phylogenetic history of the species.

Wasmann (42) treats, in a very general way, ants and their guests, dealing especially with social parasitism of the former, and the relations of the latter to their hosts. Some two thousand species of Myrmecophiles have been recorded. These Wasmann has separated, according to their relations to the host, into five classes, (1) Symphiles, or true guests; (2) Synoeketes, or indifferently tolerated guests; (3) Synechthrans, or persecuted guests; (4) Ecto- and endoparasites, and (5) Trophobiotic symphiles. A short account of the Symphiles is given. With the legionary, or driver ants are three types of guests, called by Wasmann symphilic, mimetic and protected ("Trutz") types. The latter are tolerated by the ants because they are unable to destroy them. This paper is a very excellent general account of the subject, and is illustrated with several photographic plates.

Wasmann (44) shows that in species of Atemeles living with different hosts, varieties have originated which have characters correlated with certain characters of the host. These are differences in size, color, sculpture and especially in abundance of hairs. Such forms, he believes, should be considered as varieties or subspecies and not as aberrations, as has been suggested by other writers. These variations adapt the beetle only to its summer host (Formica), each species of which has its particular form of guest, while with Myrmica, the winter host, several varieties of Atemeles may live.

Wasmann (46) describes a new Paussus from Ceylon, and gives a list of the host ants of the family Paussidae, so far as these are known. The hosts of only a small number (about one-sixth) have been recorded. The Myrmecine ants, especially of the genus Pheidole, most commonly harbor the beetles, but several live with Camponotinae, and one species, *Arthropterus brevis* West., lives with *Ectatomma metallicum*, an Australian Ponerine ant. None have been taken in nests of the Dolichoderinae or with the Dorylinae. The Paussidae are the oldest known ant guests, occurring in the Baltic amber. These amber-imbedded forms are similar to living species, and the branching of this family from the Carabidae must have taken place at a very early date. Wasmann doubts whether the structure of the beetles is the result of symphilic life, and points out the fact that Pheidologeton is known from the upper Oligocene, while the characteristic host genus, Pheidole, occurs first in the lower Miocene.

Wheeler (47) compares the ant colony to an organism, its behavior and structure with a gigantic foraminiferous Rhizopod. The nest, queen, mass of workers and files of foragers represent respectively the shell, nucleus, plasmodium and pseudopodia. The ontogenetic development of the colony is clearly comparable to that of a complete organism. The fecundated queen represents a mobile, fertilized egg, capable of disseminating the species, and also of selecting the site for the development of the colonial organism. The mass of workers make up the nutritive organ. The first of these are nourished with food derived by metabolism from the fat body of the queen, and from her useless wing muscles. The first young soon

begin to forage, to build the nest and to care for succeeding broods. When sexual forms are developed the organism may be considered to have reached maturity. The phylogenetic history is also similar to that of an organism. A complete gradation exists from the solitary female Hymenopteron, through the small colonies of primitive monomorphic workers closely resembling the female, to the large complex colonies of highly specialized, polymorphic ants, conforming in a most striking manner to the biogenetic law.

The phenomenon of budding is represented in certain ant colonies by the production of numerous queens, some of which, each accompanied by a band of workers, separate from the parent colony and found another. Alecithal eggs are comparable to the diminutive queens of parasitic ants, which, incapable by themselves of founding colonies, enter nests of alien species and use the workers as the nutritive organ, until their own young are developed. These temporary and other forms of social parasites are directly comparable to entoparasitic organisms. Ectoparasitism is represented by compound nests of two or more species which live side by side, sometimes mingling freely, but keeping their broods separate. The restitutional tendency of organisms is found in the replacing of destroyed workers by the rearing of more, and in the development by certain workers of ovaries, when the queen is removed.

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